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Emission Factor Documentation for AP-42
Section 9.1

Tilling Operations

Draft Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group

EPA Contract 68-D2-0159
Work Assignment No. II-03

MRI Project No. 4602-03

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Emission Factor Documentation for AP-42
Section 9.1

Tilling Operations

Draft Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group
Research Triangle Park, NC 27711

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NOTICE

This report is a preliminary draft. It has not been formally released by the U. S. Environmental Protection Agency and should not at this stage be construed to represent Agency policy. It is being circulated for comments on its technical merit and policy implications.

PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. II-03. Mr. Dallas Safriet was the requester of the work.

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1. INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support revisions to AP-42 Section 9.1 (formerly Section 11.2.2), Tilling Operations.

This background report consists of five sections. Section 1 consists of this introduction to the report. Section 2 gives a description of tilling operations. It includes a characterization of uses and extent of tilling operations, a description of the different types of equipment, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection and emission measurement procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the revised AP-42 section was developed. It includes the review of specific data sets, a description of how candidate emission factors were evaluated, and a summary of changes to the AP-42 section. Section 5 presents the AP-42 Section 9.1, Tilling Operations.

2. INDUSTRY DESCRIPTION

This section provides a general overview of U.S. crop production agricultural tilling operations as related to farm implement, crop, and geographical region. The generation of emissions from these activities is also described, together with characterization of the soil and other parameters affecting dust emissions. Harvesting operations will not be considered, but are discussed elsewhere in AP-42 Chapter 9.

2.1 INDUSTRY CHARACTERIZATION[1-2]

The United States is a major agricultural producer with more than 300 million acres of cropland. Approximately 50 percent of the land used for crops is located in the following eight states (listed in descending order): Kansas, North Dakota, Iowa, Illinois, Texas, Nebraska, Minnesota, and South Dakota. The major crops and the respective top-producing states include corn (Iowa), soybeans (Illinois), wheat (North Dakota), sorghum for grain, (Texas), barley (North Dakota), and oats (South Dakota). Table 2-1 lists the acreage farmed for different crops by State, in 1990. In 1993, the highest total acreages devoted to individual crops were 62.6 million acres for wheat; 63.0 million acres for corn; 56.4 million acres for sorghum; and 12.8 million acres for cotton.

Agricultural crop production requires tilling of the surface soil with farm implements. The two universal objectives of agricultural tilling are the creation of the desired soil structure to be used as the crop seedbed and the eradication of weeds. During a tilling operation, dust particles released from the loosening, overturning, and pulverization of the soil are released into the atmosphere. Tilling activities are known to generate significant amounts of fugitive particulate matter, encompassing a wide range of particle sizes.

2.2 PROCESS DESCRIPTION[3-8]

During agricultural tilling operations, surface soil is loosened and pulverized by application of force from farm implements (wheels, blades, tines, etc.) that are either tractor-drawn or self-propelled. A desirable soil structure is one in which large pores extend from the surface to the water table or drains. This structure helps to provide the right proportion of air and water for plant roots to

TABLE 2-1. ACREAGE HARVESTED BY STATE: 1990 TO 1993

State	1990[a]	1991[a]	1992[a]	1993 (Prel.)[a]
U.S.[b]	308,318	303,864[c]	307,171[c]	295,918[c]
AL	2,338	2,229	2,130	2,116
AZ	802	770	736	695
AR	8,080	7,863	8,110	8,165
CA	4,789	4,396	4,459	4,403
CO	5,862	5,591	5,395	5,625
CT	129	125	128	125
DE	496	556	515	499
FL	1,076	1,048	1,071	1,046
GA	3,788	3,777	3,693	3,523
HI	79	74	68	64
ID	4,175	4,079	4,006	4,322
IL	22,759	22,906	23,237	21,934
IN	11,485	11,527	11,709	11,767
IA	23,276	23,356	23,666	21,916
KS	20,978	20,712	20,266	20,454
KY	5,505	5,495	5,419	5,419
LA	4,346	3,665	4,029	3,729
ME	361	351	375	373
MD	1,551	1,562	1,619	1,569
MA	135	136	135	134
MI	6,510	6,733	6,817	6,751
MN	18,765	18,692	19,301	16,940
MS	4,719	4,478	4,855	4,708
MO	12,685	12,900	12,904	11,642
MT	8,926	8,687	8,369	8,891
NE	18,044	18,366	18,330	17,917
NV	520	495	403	527
NH	91	92	103	106
NJ	361	380	391	413
NM	880	1,042	1,051	995
NY	3,538	3,443	3,185	3,150
NC	4,336	4,397	4,519	4,127
ND	21,014	20,655	21,011	19,782
OH	10,132	9,972	10,087	10,037
OK	9,688	8,518	9,392	8,771
OR	2,290	2,260	2,147	2,260
PA	4,094	4,067	4,065	4,035
RI	10	10	11	12
SC	2,046	1,824	1,885	1,603
SD	15,528	15,606	15,858	14,223
TN	4,477	4,379	4,326	4,408
TX	18,544	17,714	18,769	18,524
UT	992	973	990	1,031
VT	441	434	463	434
VA	2,725	2,656	2,705	2,659
WA	3,999	3,861	3,957	4,227
WV	668	615	639	621
WI	8,550	8,449	8,096	7,498
WY	1,735	1,899	1,723	1,804

Source: Reference 1.
[a]Acreage figures are in thousand (1,000) acres.
[b]Excludes Alaska.
[c]Includes sunflower and sugarbeet acreage unallocated by State.

absorb nutrients from the soil. Table 2-2 provides definitions of the terminology used to describe tillage systems. Additional discussions of tillage operations is provided in Reference 8.

TABLE 2-2. TILLAGE DEFINITIONS

Primary Tillage is an operation that loosens and fractures the soil to reduce strength and to bring or mix residues and fertilizers into the tilled layer. The implements ("tools") used for primary tillage include moldboard, chisel and disk plows; heavy tandem, offset and one-way disks; subsoilers; and heavy-duty, powered rotary tillers. These tools usually operate at least 6 inches (15.4 cm) deep and produce a rougher soil surface than do secondary tillage tools
Secondary Tillage is used to kill weeds, cut and cover crop residues, incorporate herbicides and prepare a well pulverized seedbed. Secondary tillage tools include light- and medium-weight disks, field cultivators, row cultivators, rotary hoes, drags, powered and unpowered harrows or rotary tillers, rollers, ridge- or bed-forming implements, and numerous variations or combinations of these. They usually operate at depths of less than 5 inches (12.7 cm).
Conservation Tillage is defined as tillage operations that minimize soil erosion due to wind and water. Erosion resistance is achieved either by protecting the soil surface with crop residue or growing plants, or by increasing the surface roughness or soil permeability.
Conventional Tillage refers to the sequence of tillage operations traditionally or most commonly used in a given geographic area to prepare a seedbed and produce a given crop.
Clean Tillage involves a sequence of operations (often involving conventional tillage) that prepare a seedbed having essentially no plant residues on the soil surface.
Reduced Tillage refers to any system that less intensive and less aggressive than conventional tillage.

Soil preparation, seed planting, and land maintenance operations typically include plowing, disking, fertilizing, applying herbicides and insecticides, bedding, flattening and bed firming, planting, and cultivating. Plowing consists of cutting loose, granulating, and inverting the soil and turning under the organic residue. Disking is performed to cut the soil with steel disks that rotate as the implement is pulled through the field. Liquid fertilizers are commonly applied using tines that extend below the soil. Sweeps or undercutters loosen the soil and cut off the weeds, but leave the surface residue in place. Irrigated farming practices involve many of the same operations discussed above, but also involve the shaping of beds and leveling of land (land planing) to promote the controlled flow of surface water.

Dryland farming employs a variety of implements, as shown in Table 2-3. The conventional moldboard (self-scouring) plows, chisels, and disks of the 1970's have been significantly replaced by modified chisels, sweeps, disks, coulters, and subsurface cutters and because of the improved designs, they are used less frequently than former implements. Often the depth of soil disturbance using

TABLE 2-3. AGRICULTURAL FIELD EQUIPMENT

Moldboard (self-scouring) plow
Paraplow/Paratill[a]
V ripper/subsoiler (indicate depth and spacing)[a]
Chisel plow with: Sweeps[a] Straight chisel points Twisted points (shovels)
Coulter chisel plow with: Sweeps Straight chisel points Twisted points (shovels)
Disk chisel plow with: Sweeps Straight chisel points Twisted points (shovels)
Disk offset (Primary, over 9 inch [in.] spacing) (Finishing, 7in.—9 in. spacing)
Tandem disk (As secondary operation, 7 in.—9 in. spacing) (After harvest, before other tillage)
Field cultivator: Duckfoot points Sweeps or shovels (6 in.—12 in.)[a] Sweeps (12 in.—24 in.)[a]
Finishing tools: Combination (disks, shanks, levelers) Combination (rollers and spring teeth)[a] Spike-tooth barrow[a] Rotary tiller (3 in. deep)
Drills: Hoe openers Double-disk openers[a] No-till coulters (ripple or bubble, on stubble)[a] No-till coulters (fluted, on stubble)[a]
Planters: Runners[a] Double-disk openers[a] Staggered double-disk openers[a] Ridge-till
No-till planters with: Smooth coulters[a] Ripple coulters[a] Fluted coulters[a] Two or three fluted coulters[a] Sweeps[a] Furrowing disks, spikes, or brushes[a]
Anhydrous ammonia applicator[a] Anhydrous ammonia applicator with closing disks
Fertilizer spreader
Herbicide applicator
Manual hoeing and roto-tilling

Source: Reference 3.
[a]Low disturbance equipment (see text).

current tilling equipment is less than produced by conventional tilling equipment. These changes influence the total soil erosion, perhaps reducing wind and water erosion levels by 50 percent compared to clean tillage. The equipment types indicated in Table 2-3 as "low disturbance" leave greater than 50 percent fragile residue (e.g., soybean).

The Soil Conservation Service of the U.S. Department of Agriculture (USDA-SCS)* has recommended that a minimum of 30 percent of the crop residue on the soil surface be preserved by using reduced tillage and tillage with newly designed farm implements. In 1991, approximately 55 million acres of the U.S. cropland were farmed using methods that left at least 30 percent crop residue on the surface. From 1989 to 1992, no-till farming in the Midwest doubled in acreage to 9.8 million acres, while mulch tillage leveled off at 22 million acres.

The typical number of tillage operations by type of crop grown in California is shown in Table 2-4. Earlier estimates of three tilling operations as a national average for row crops is used by EPA for PM-10 emission trends analysis.

2.3 EMISSIONS[6]

Fugitive dust is caused by loosening and pulverizing surface soil during tilling operations. Farm tillage implements cut through and break up the dirt, releasing soil particles into the air as the soil is handled and dropped to the surface. Dust emissions are greatest when the soil is dry and during final seedbed preparation.

Dust emissions from agricultural tilling are proportional to the acreage of land tilled and tilling frequency. Emissions are also dependent on the degree of mechanical agitation of the soil and the soil friability. The tilling parameters that have the potential for influencing the generation of fugitive dust include:

1. Dry texture of the surface soil;

*The Soil Conservation Service (SCS) of the U.S.D.A. has recently been renamed the Natural Resource Conservation Service.

TABLE 2-4. CALIFORNIA TILLAGE OPERATIONS

Crop	No. of typical operations[a]	Land area tilled, %	No. of acre pass per acre[b]
Existing fruit and nut trees	2	5	0.10
New fruit and nut trees	3	5	0.15
Grapes	7	5	0.35
Alfalfa and irrigated pasture	8	20	1.60
Dry pasture	0	0	0
Asparagus	2	100	2
Carrots, onion, garlic and sweet corn	5	100	5
Corn, cotton, sorghum and soybeans	6	100	6
Barley, oats, safflower, wheat, other field crops, melons, lettuce, pepper, potatoes, sweet potatoes, snap beans, and other vegetables	7	100	7
Spinach and peas	8	100	8
Sunflower, lima beans, squash and cucumber	9	100	9
Dry beans, sugar beets, broccoli, cauliflower and cabbage	10	100	10
Tomatoes	11	100	11
Rice	13	100	13

Source: Reference 6.
[a]Includes all land preparation activities. For example, land preparation for dry beans entails: plow or chisel (1x), disk (1x), triplane (2x), land plan (3x), fertilizer/herbicide application (1x), and final disk (2x) for a total of 10 operations.
[b]Number of acre passes is the product of the first column times the second column.

2. Moisture content of the surface soil;
3. Depth of soil disturbed (typically the top 2 to 6 inches of soil);
4. Degree of soil disturbance (i.e., mechanical agitation); and
5. Speed of the equipment.

Dust emissions from agricultural tilling have been found to vary directly with the silt content (defined as particles less than 75 micrometers in diameter) of the surface soil depth (0 to 10 cm [0 to 4 in.]). The soil silt content is determined by measuring the proportion of dry soil that passes a 200 mesh screen, using ASTM-C-136 method. Note that this definition of silt differs from that customarily used by soil scientists, who define silt as particles from 2 to 50 micrometers in diameter (in the disaggregated state).

Although soil dustiness is inversely related to moisture content, field measurements indicate that dust emissions from agricultural tilling significantly correlated to surface soil moisture. This reflects the fact that most tilling is performed under dry soil conditions, as were the majority of the field tests.

Available test data also indicate no substantial dependence of emissions on the type of conventional tillage implement, if operating at a typical speed (for example, 8 to 10 km/hr [5 to 6 mph]). However, because many new farm implements are designed to cause less soil disturbance during tilling, quantifiable reductions in emission rates are anticipated.

Because some agricultural chemicals bind to the soil particles that become suspended in air, these chemicals may be resuspended with the soil during agricultural tilling operations. Estimates of chemical emissions generated by tilling soil treated with fertilizers, herbicides, and pesticides are usually assumed to be proportional to the mass fraction of chemical attached to the surface soil. These quantities are a function of the chemical application rate, volatility, solubility, adsorptivity, and degradation rate of the chemical.

2.4 CONTROL METHODS[6,9]

Although a number of particulate emission controls, in the form of resource (soil) conservation practices, have been suggested for agricultural operations, little data on demonstrated control efficiencies are available. In addition because of the broad range of soil types, crop types, and climatic conditions, the control efficiency resulting from even a single conservation practice can be expected to vary substantially from one application to another.

The limited available information on control efficiency estimates for agricultural controls is reviewed below. These controls take the form of operational modifications that affect soil preparation or seed planting operations. Harvesting implements are already designed to garnish the crop in the most effective manner. Because generally there are no cultural techniques to substitute for harvesting, emission controls must take the form of add-on devices.

It is important that all tillage operations be conducted sparingly because frequent tillage leads to soil surface smoothing and clod pulverization, which in turn increase the dustiness of the soil. The use of a "dust mulch" as a moisture barrier is especially to be avoided because of its high potential for dust emissions during subsequent tilling operations or high wind events. Planting and seeding equipment should preserve as much residue as possible and place the seed in moist, firm soil to promote rapid germination. Although field tests show no significant correlation of tillage emissions to wind speed, tilling under high wind conditions should be avoided. Coarse particle emissions will redeposit on the land under low wind conditions.

Soil cloddiness and surface roughness, both of which mitigate against subsequent wind erosion, are affected by the type of tillage implement used. For example, the moldboard plow produces a rougher, more cloddy surface with higher mechanical stability of clods than the one-way disk or subsurface sweep. In anticipation of a high wind event, emergency tillage practices are invoked; these practices employ tillage implements that specifically bring clay to the surface for increased cloddiness and roughen the land to prevent wind erosion. More clods are produced if the soil is moist than if it contains a low or intermediate moisture content.

Conservation practices involving operational modifications to tilling of the soil include the use of novel low-disturbance implements or the alteration of cultural techniques to eliminate some operations altogether. Estimated PM-10 efficiencies for crop-specific operational modifications to tilling are presented in Table 2-5. It should be noted that most of these conservation practices also reduce the wind erodibility of the soil. These particular practices are discussed below.

TABLE 2-5. ESTIMATED PM-10 EFFICIENCIES FOR AGRICULTURAL CONTROLS[6]

Control technique	Operation affected	Estimated control efficiency (percent) by crop for applicable techniques							
		Cotton	Barley	Alfalfa	Rice	Corn	Wheat	Tomatoes	Lettuce
Punch planter	Planting	50				50			50
Herbicides	Cultivation or soil preparation	100	25[a]	25[a]	[b]	100	25[a]	100	100
Sprinkler irrigation	Land planing	90	90	90	[c]	90	90	90	90
Laser-directed land plane	Land planing or floating	30	30	30	30	30	30	30	30
Develop high quality alfalfa	All soil preparation operations			75					
Double crop corn with wheat	Disking or plowing					50[d]			
Aerial seeding	Planting			50	3[e]		50		

[a]Eliminates only some soil preparation operations, whereas in other cases, all cultivation operations are eliminated.
[b]Herbicides already applied by airplane for majority of acreage.
[c]Flood irrigation necessary.
[d]Fifty percent control only for double-cropped acreage.
[e]Seeding already performed by airplane for majority of acreage.

The *punch planter* is a novel implement which might have applications for emissions reduction from planting cotton, corn, and lettuce. It is already being used in sugar beet production. The punch planter punches a hole and places the seed into it, as opposed to conventional planters which make a trough and drop the seeds in at a specified spacing. The advantage is that punch planters can leave much of the surface soil and surface crop residues undisturbed. Large-scale use of the punch planters would require initial capital investments by the farming industry for new equipment.

Herbicides for weed control is a cultural practice which could reduce emissions from cultivation for most row crops with wide enough spacing for cultivation and for some close-grown crops like wheat. The use of herbicides, however, must be balanced against potential increased herbicide emissions caused by wind and by water runoffs.

Sprinkler irrigation is an existing cultural technique which could produce fugitive emission control for any crop which is currently irrigated by surface watering systems. Sprinkler irrigation eliminates the need for the extensive land planing operations that surface irrigation requires. However, the capital investment for sprinkler irrigation equipment and the increased costs of pumping the water are major deterrents.

The *laser-directed land plane* is a novel implement which might yield some emissions controls for surface-irrigated crops. Laser-guided grading equipment has been used in construction for years and can be expected to reduce the amount of land planing required due to its more precise leveling blade. This device might be retrofitted to existing land planes, but capital investment funds are required.

The developing of *long lasting varieties of alfalfa* with high leaf protein content would help to reduce emissions, because present practices require replanting every 3 to 5 years. New varieties already exist which can last up to 20 years, but the protein content is low. If longevity and quality could be combined, the soil would not have to be prepared so often, thus yielding a subsequent reduction in emissions

Double-cropping corn with wheat or other grain instead of corn with corn might reduce fugitive emissions. Since corn provides a high quantity of stubble, it must be plowed or disked under the soil surface. The beds must then be formed and shaped for the next corn seed planting. If wheat or another grain were grown on a bedded field, then corn could be planted on the beds after the wheat harvest and stubble removal. The beds would require only reshaping. This would eliminate a plowing or disking operation and a bed-forming operation while adding a less dusty wheat stubble removal operation.

Finally, ***aerial seeding***, which is already used in rice production, would probably reduce emissions somewhat from alfalfa and wheat production. However, at least in the case of wheat, the aerially applied seed must be covered with soil. This seed covering operation will produce dust, but it may be less dust than a ground-planting operation would produce.

Because of the broad range of soil types, climatic conditions, and crop types associated with agricultural operations, it is not possible to develop an effective predetermined PM-10 emission control strategy for application to each type of agriculture operation. The candidate control measures discussed above are therefore general in scope; each control measure may not be applicable under every circumstance.

The preferred approach to implementing regional control measures for agricultural operations would be through the use of group and individual conservation plans. The USDA-SCS is participating in the development and evaluation of PM-10 control measures. As control measures are tested and verified for effectiveness, they will be placed in the Field Office Technical Guides (FOTG's) for the various regions. This activity will support the development of customized control strategies for each agricultural operation related to each crop category.

References for Section 2

1. *Agricultural Statistics 1993*, U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, D.C. August 1994.

2. *Statistical Abstract of the United States 1994*, 114th edition, U.S. Department of Commerce, Bureau of the Census, Washington, D.C. September 1994.

3. R. Fee, "Manage Crop Residue One Trip At A Time," *Successful Farming*, March 1992.

4. Telephone communication from M. A. Grelinger, Midwest Research Institute, Kansas City, MO, to D. Schertz, SCS National Agronomist, U.S. Department of Agriculture, Washington, D.C. September 1992.

5. J. Walter. "Mulch Tillage Makes a Move," *Successful Farming*, September 1992.

6. T. H., Cuscino, Jr., J. S. Kinsey, and R. Hackney, *The Role of Agricultural Practices in Fugitive Dust Emissions*, Final Report prepared by Midwest Research Institute for the California Air Resources Board, Sacramento, California, 1981.

7. C. Cowherd, Jr., C. M. Guenther, and D. D. Wallace, *Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips and Construction Sites*. EPA-450/3-74-085, U. S. Environmental Protection Agency, Research Triangle Park, NC, November 1974.

8. J. C. Siemen, R. G. Hoeft and A. W. Pauli, *Soil Management*, Deere and Company, Moline, IL, 1993.

9. A. Caughron and C. Cowherd, Jr., *Serious Area Example BACM Application: Example Area 1*. EPA Contract No. 68-03-0031, Work Assignment I-12, U. S. Environmental Protection Agency, Research Triangle Park, NC, January 1995.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

This section discusses methods used to identify and evaluate emission test data and reviews the applicable emission test methods.

3.1 LITERATURE SEARCH AND SCREENING[1]

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 background files located in the Emission Factor and Inventory Group (EFIG) were reviewed for information on the agricultural tilling processes and emissions. Information on the agricultural industry, including number of harvested acres by crop and State, was obtained from the *Census of Agriculture*, and other sources. Frequent contact with the western States PM-10 BACM Working Group over the past 2 years provided for tracking of recent agricultural studies. As such studies were identified, State and District offices were contacted about the availability of test reports. Also the USDA liaison to EPA on PM-10 was consulted for information on emission control technology.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 DATA QUALITY RATING SYSTEM[2]

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B—Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C—Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D—Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[2]

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer.

3.4 EMISSION TEST METHODS[3-5]

Fugitive dust emission rates and particle size distributions are difficult to quantify because of the diffuse and variable nature of such sources and the wide range of particle sizes, including particles which deposit immediately adjacent to the source. Standard source testing methods, which are designed for application to confined flows under steady-state, forced-flow conditions, are not suitable for the measurement of fugitive emissions unless the plume can be drawn into a forced-flow system. The available source testing methods for fugitive dust sources are described in the following paragraphs.

For the field measurement of fugitive mass emissions from mechanical entrainment processes, two basic techniques have been defined:

1. The upwind—downwind method involves the measurement of upwind and downwind particulate concentrations, utilizing ground-based samples under known meteorological conditions, followed by a calculation of the source strength (mass emission rate) with atmospheric dispersion equations.[3]

2. The exposure-profiling method involves simultaneous, multipoint measurements of particulate concentration and wind speed over the effective cross section of the plume, followed by a calculation of the net particulate mass flux through integration of the plume profiles.[4]

3.4.1 Upwind-Downwind Method

The upwind-downwind method (see Figure 3-1) involves the measurement of airborne particulate concentrations both upwind and downwind of the pollutant source. The number of upwind sampling instruments depends on the degree of isolation of the source operation of concern (i.e., the absence of interference from other sources upwind). Increasing the number of downwind instruments improves the reliability in determining the emission rate by providing better plume definition. In order to reasonably define the plume emanating from a point source, instruments need to be located at a minimum of two downwind distances and three crosswind distances. The same sampling requirements pertain to line sources except that measurement need not be made at multiple crosswind distances.

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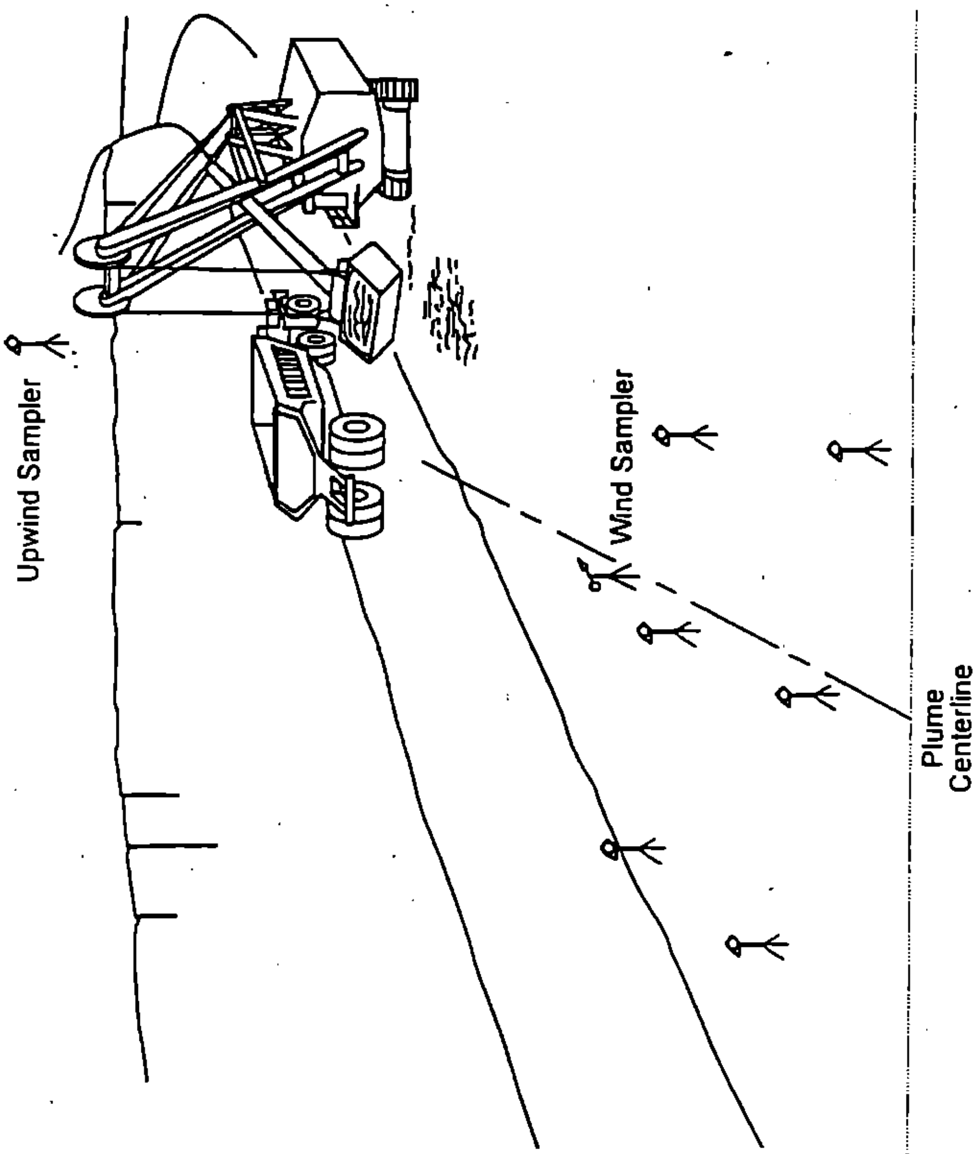

Figure 3-1. Illustration of upwind-downwind technique (for loading operation).

Net downwind (i.e., downwind minus upwind) concentrations are used as input to atmospheric dispersion equations (normally of the Gaussian type) to back-calculate the particulate emission rate (i.e., source strength) required to generate the pollutant concentrations measured. Emission factors are obtained by dividing the calculated emission rate by the source extent. A number of meteorological parameters must be concurrently recorded for input to this dispersion equation. As a minimum, the wind direction and speed must be recorded on-site.

Because the sampling array is typically located at least 50 m from the downwind edge of the source (in part, to provide for valid application of the dispersion model), the measured ambient air impacts of the source are significantly less than those observed near the source. Therefore, a sampling duration exceeding 6 hours is usually required to collect a reliably quantifiable PM-10 sample mass, even with a high-volume sampling system.

It should be noted that the upwind-downwind method has significant limitations with regard to the development of source-specific emission factors. The major limitations are as follows:

1. Overlapping plumes from other nearby sources may preclude the determination of the specific contribution of an individual source.

2. Because of the impracticality of adjusting the locations of the sampling array for shifts in wind direction during multi-hour period of sampling, it may be questionable to assume that the plume position is fixed in the application of the dispersion model.

3. In the case of an area source, the usual assumption that the source is uniformly emitting may not allow for a realistic representation of spatial variation in source activity.

4. The typical use of an uncalibrated atmospheric dispersion model introduces the possibility of substantial error. According to Reference 5, the error in the calculated emission rate can be as much as a factor of three, even if the stringent requirement of unobstructed dispersion from a simplified source configuration is met (e.g., constant emission rate from a single point).

3.4.2 Exposure-Profiling Method

As an alternative to conventional upwind-downwind sampling, the exposure-profiling technique (Figure 3-2) utilizes the isokinetic profiling concept, which is the basis for conventional ducted source testing (EPA Method 5), except that, in the case of exposure-profiling, the ambient

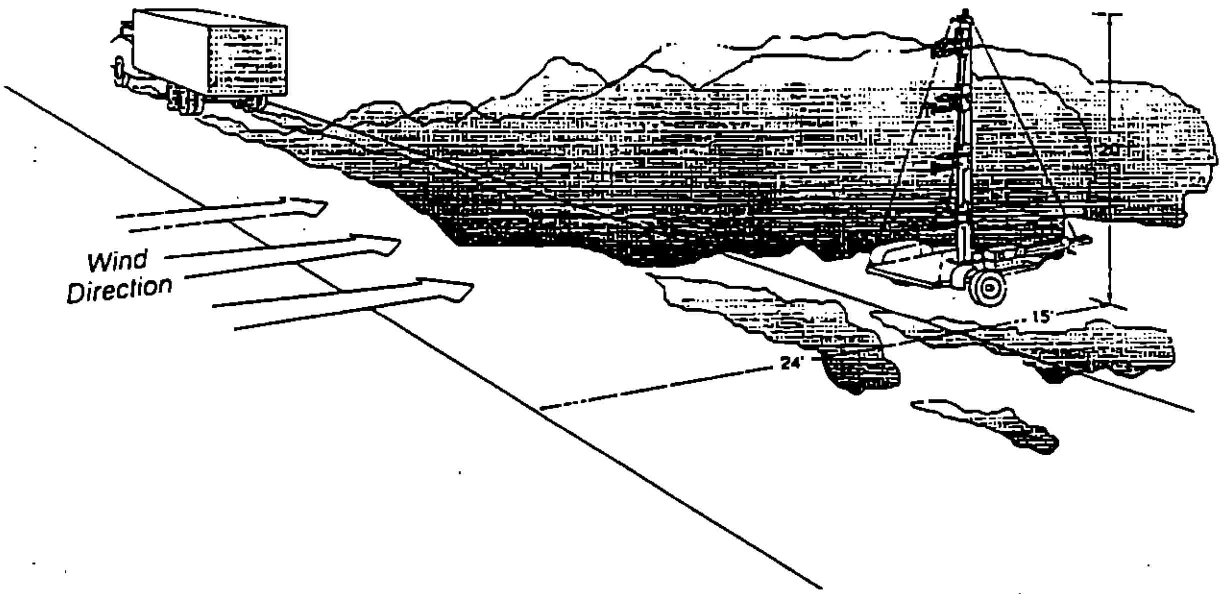

Figure 3-2. Illustration of exposure profiling technique.

wind directs the plume to the sampling array. The passage of airborne particulate matter immediately downwind of the source is measured directly by means of a simultaneous, multipoint sampling of particulate concentration and wind velocity over the effective cross section of the fugitive emissions plume. Unlike the conventional upwind-downwind method, exposure-profiling uses a mass-balance calculation scheme rather than requiring an indirect calculation through the application of a generalized atmospheric dispersion model.

For the measurement of nonbuoyant fugitive emissions using exposure profiling, sampling heads are distributed over a vertical network positioned just downwind (usually about 5 m) from the source. Particulate sampling heads are symmetrically distributed over the concentrated portion of the plume containing at least 80 percent of the total mass flux. A vertical line grid of at least three samplers is sufficient for the measurement of emissions from line or moving point sources, while a two-dimensional array of at least five samplers is required for quantification of the fixed virtual point source of emissions. At least one upwind sampler must be operated to measure the background concentration, and wind speed must be measured concurrently onsite.

Only in the case of large area sources does exposure profiling become infeasible because of the impracticality of using tall towers for sample support. In that case, the upwind-downwind method may be necessary but with the limitations described previously in Section 3.4.1.

Because of the near-source location of the sampling array, a sampling duration of about 1 hour is usually sufficient for reliably quantifiable amounts of PM-10 sample mass. Over this relatively short sampling duration, wind speed and direction can be anticipated to remain relatively consistent.

To achieve isokinetic sampling, the sampling intakes are pointed into the wind and the sampling velocity matched to the mean wind velocity approaching the sampling intake. The isokinetic velocity ratio should lie between 0.8 and 1.2, and the sampler orientation should be adjusted whenever it differs from the mean wind direction by more than 30°. A minimum wind velocity of 1.8 meters per second (m/s) (4 mph) is usually required to assure acceptable consistency in wind speed and direction.

Isokinetic sampling is not strictly required for determination of PM-10 concentration because of the relatively weak inertial properties of fine particles. Alternatively, a PM-10 sampling inlet (e.g., one designed to capture only PM-10, independent of the prevailing wind speed) may be used to measure PM-10 concentrations.

The particulate emission rate is obtained by a spatial integration of the distributed measurements of exposure (accumulated mass flux), which is the product of mass concentration and wind speed:

$$R = \int_A C(h,w)u(h,w)dhdw$$

where:

R = emission rate, g/sec

C = net particulate concentration, g/m^3

u = wind speed, m/sec

h = vertical distance coordinate, m

w = lateral distance coordinate, m

A = effective cross-sectional area of plume, m^2

Usually, a numerical integration scheme is used to calculate the emission rate.

3.4.3 Emission Factor Derivation

Usually the final emission factor for a given source operation, as presented in a test report, is derived simply as the arithmetic average of the individual emission factors calculated from each test of that source. Frequently the range of individual emission factor values is also presented.

As an alternative to the presentation of a final emission factor as a single-valued arithmetic mean, an emission factor may be presented in the form of a predictive equation derived by regression analysis of test data. Such an equation mathematically relates emissions to parameters when characterize source conditions. These parameters may be grouped into three categories:

1. Measures of source activity or energy expended (e.g., the speed of a tractor traveling on an agricultural field).

2. Properties of the material being disturbed (e.g., the content of suspendable fines on the surface of the agricultural field).

3. Climatic parameters (e.g., a number of precipitation-free days per year on which emissions tend to be at a maximum).

An emission factor equation is useful if it is successful in "explaining" much of the observed variance in emission factor values on the basis of corresponding variances in specific source parameters. This enables more reliable estimates of source emissions on a site-specific basis.

3.5 EMISSION FACTOR QUALITY RATING SCHEME USED IN THIS STUDY[6]

The uncontrolled emission factor quality rating scheme used for tilling operations represents a refinement of the rating system developed by EPA for AP-42 emission factors, as described in Section 3.3. The scheme entails the rating of test data quality followed by the rating of the emission factor(s) developed from the test data.

Test data that were developed from well documented, sound methodologies are assigned an A rating. Data generated by a methodology that is generally sound but either does not meet a minimum test system requirements or lacks enough detail for adequate validation receives a B rating.

In evaluating whether an upwind-downwind sampling strategy qualified as a sound methodology, the following minimum test system requirements are used. A minimum of five particulate measuring devices must be operated during a test, with one device located upwind and the other located at two downwind and three crosswind distances. The requirement of measurements at crosswind distances is waived for the case of line sources. Also wind direction and speed must be monitored concurrently onsite.

The minimum requirements for a sound exposure profiling program are the following. A one-dimensional, vertical grid of at least three samplers is sufficient for measurement of emissions from one or moving point sources while a two-dimensional array of at least five samplers is required for quantification of fixed virtual point source missions. At least one upwind sampler must be operated to measure background concentration, and wind speed must be measured onsite. When both the upwind-downwind and the exposure profiling methodologies are applicable, the profiling methodology is usually preferable because of the uncertainties introduced by the limitations of the upwind-downwind methodology as described in Section 3.4.1.

Neither the upwind-downwind nor the exposure profiling method can be expected to produce A-rated emissions data when applied to large, poorly defined area sources, or under very light and variable wind flow conditions. In these situations, data ratings based on degree of compliance with minimum test system requirements were reduced one level (letter).

After the test data supporting a particular single-valued emission factor are evaluated, the criteria presented in Table 3-1 are used to assign a quality rating to the resulting emission factor. These criteria were developed to provide objective definition for: (a) representativeness and (b) levels of variability within the data set for the source category.

TABLE 3-1. QUALITY RATING SCHEME FOR SINGLE-VALUED EMISSION FACTORS

Code	No. of test sites	No. of tests per site	Total No. of tests	Test data variability[a]	Adjustment for EF rating[b]
1	≥3	≥3	—	<F2	0
2	≥3	≥3	—	>F2	-1
3	2	≥2	≥5	<F2	-1
4	2	≥2	≥5	>F2	-2
5	—	—	≥3	<F2	-2
6	—	—	≥3	>F2	-3
7	1	2	2	<F2	-3
8	1	2	2	>F2	-4
9	1	1	1	—	-4

[a]Data spread in relation to central value. F2 denotes factor of two.
[b]Difference between emission factor rating and test data rating.

The rating system obviously does not include estimates of statistical confidence, nor does it reflect the expected accuracy of fugitive dust emission factors relative to conventional stack emission factors. It does, however, serve as useful tool for evaluation of the quality of a given set of emission factors relative to the entire available fugitive dust emission factor database.

Minimum representativeness is defined in terms of number of test sites and number of tests per site. These criteria were derived from two principles:

1. Traditionally, three tests of a source represent the minimum requirement for reliable quantification.

2. More than two test sites are needed to provide minimum representativeness.

The level of variability within an emission factor data set is defined in terms of the spread of the original emission factor data values about the mean or median single-valued factor for the source category. The fairly rigorous criterion that all data points must lie within a factor of two of the central value was adopted. It is recognized that this criterion is not insensitive to sample size in that for a sufficiently large test series, at least one value may be expected to fall outside the factor-of-two limits. However, this is not considered to be a problem because most of the current single-valued factors for fugitive dust sources are based on relatively small sample sizes.

Development of quality ratings for emission factor equations also requires consideration of data representativeness and variability, as in the case of single-valued emission factors. However, the criteria used to assign ratings (Table 3-2) are different, reflecting the more sophisticated model being used to represent the test data. As a general principle, the quality rating for a given equation should lie between the test data rating and the rating that would be assigned to a single-valued factor based on the test data. The following criteria were established for an emission factor equation to have the same rating as the supporting test data:

1. At least three test sites and three tests per site, plus an additional three tests for each independent parameter in the equation.

2. Quantitative indication that a significant portion of the emission factor variation is attributable to the independent parameter(s) in the equation.

Loss of quality rating in the translation of these data to an emission factor equation occurs when these criteria are not met. In practice, the first criterion is far more influential than the second in rating an emission factor equation, because development of an equation implies that a substantial portion of the emission factor variation is attributable to the independent parameter(s). As indicated in Table 3-2, the rating is reduced by one level below the test data rating if the number of tests does not meet the first criterion, but is at least three times greater than the number of independent parameters in the equation. The rating is reduced two levels if this supplementary criterion is not met.

TABLE 3-2. QUALITY RATING SCHEME FOR EMISSION FACTORS EQUATIONS

Code	No. of test sites	No. of tests per site	Total No. of tests[a]	Adjustment for EF rating[b]
1	≥3	≥3	≥(9 + 3P)	0
2	≥2	≥3	≥3P	-1
3	≥1	—	<3P	-1

[a]P denotes number of correction parameters in emission factor equation.
[b]Difference between emission factor rating and test data rating.

The rationale for the supplementary criterion follows from the fact that the likelihood of including "spurious" relationships between the dependent variable (emissions) and the independent parameters in the equation increases as the ratio of number of independent parameters to sample size increases. For example, a four parameter equation based on five tests would exhibit perfect explanation ($R^2 = 1.0$) of the emission factor data, but the relationships expressed by such an equation cannot be expected to hold true in independent applications.

References for Section 3

1. M. D. Zeldin, The BACM Working Group: A Multi-Agency Cooperative Approach for Development PM-10 Serious Area SIPs," presented at The A&WMA Specialty Conference on Particulate Matter: Health and Regulatory Issues Meeting, April 1995.

2. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

3. H. J. Kolnsberg, *Technical Manual for the Measurement of Fugitive Emissions: Upwind/Downwind Sampling Method for Industrial Fugitive Emissions*. EPA-600/2-76-089, NTIS Publication No. PB253092, U. S. Environmental Protection Agency, Research Triangle Park, NC, 1976.

4. C. Cowherd, Jr., et al., *Development of Emission Factors for Fugitive Dust Sources*, EPA Publication No. EPA-450/3-74-037, NTIS Publication No. PB238262, U. S. Environmental Protection Agency, Research Triangle Park, NC, 1974.

5. D. B. Turner, *Workbook of Atmospheric Dispersion Estimates* (AP-26). U. S. Environmental Protection Agency, Research Triangle Park, NC, 1970.

6. C. Cowherd, et al., *Fugitive Dust Emission Factor Update for AP-42*. EPA Contract No. 68-02-3177, Work Assignment 25, U. S. Environmental Protection Agency, Research Triangle Park, NC, 1983.

4. REVIEW OF SPECIFIC DATA SETS

This section presents new test data for agricultural tilling operations and summarizes the proposed changes to the AP-42 section.

4.1 REVIEW OF SPECIFIC DATA

Beyond the two studies which formed the basis for the AP-42 emission factor equation presented in the current Section 11.2.2, Tilling Operations, only one other test report was identified.

4.1.1 Reference 1

This study developed an emission factor equation for agricultural tilling which includes the use of a disk, land plane, or sweep plow. The data base evaluated in this reference included the earlier tests of Cowherd, et al. (1974) that employed the same sampling procedure (exposure profiling) as described in Section 3.4. The emission factor calculation scheme used in this reference is described in Section 3.4.

The exposure profiling system employed in both studies consisted of a 6-meter vertical tower (located approximately 5-meters downwind of the source) supporting sampling intakes and anemometers. Each sampler had a directional intake, and the flow was adjustable to provide for isokinetic sampling. Cascade impactors with cyclone preseparators were used for particle sizing. Because the test data from both studies were collected using a well-documented sound methodology, the data are rated A. Table 4-1 describes the range of conditions tested.

The emission factor equations derived from the results of these studies are as follows:

$$E_{TP} = 5.38(s)^{0.6}$$
$$E_{IP} = 1.35(s)^{0.6}$$
$$E_{FP} = 0.538(s)^{0.6}$$

TABLE 4-1. AGRICULTURAL TILLING, RANGE OF TEST CONDITIONS, AND RATING

Date and No. of tests	No. of sites	Range of conditions				Rating code	Rating
		Soil silt content, %	Soil moisture content, %	Tractor speed, mph	Implement type		
4/80 18 tests	6	1.7-88	2.1-15.9	3-5	Disc, land plane, sweep-plow	1,2	A,B[a]

[a]The A rating applies to the total particulate emission factor, whereas a rating of B is assigned to the IP (<15 μm aerodynamic diameter) and FP (<2.5 μm aerodynamic diameter) (inhalable and fine particulate) emission factor equations. See text for explanation.

where:

E_{TP} = total particulate emission factor (kg/hectare)

E_{IP} = inhalable ($< 15\ \mu m$) particulate emission factor (kg/hectare)

E_{FP} = fine ($< 2.5 \mu m$) particulate emission factor (kg/hectare)

s = soil silt content (percent)

The predictive emission factor equation for total particulate matter was derived through a multiple regression analysis of the 18 data sets (emission rates, soil silt content values and soil moisture content values)–11 tests from California (Reference 1) and 7 tests from Kansas (Reference 2). It was found that the moisture variable did not improve the predictive capability of the equation whereas the silt content did. The equations for particles smaller than 15 μm and 2.5 μm aerodynamic diameter were calculated by multiplying the total particulate equation by the appropriate mass fractions consisting of particles in the respective size ranges. However, these mass fractions were not measured in the seven Kansas tests. For this reason, and for others stated in Reference 1, these latter two equations are less precise. Thee equation for total particulate matter is rated A, but the inhalable and fine particulate factors are rated B for reasons stated above. The rating codes refer to Table 3-2.

4.1.2 Reference 3

The objective of this study was to develop emission factors for agricultural operations that have "the highest propensity for dust generation" in the San Joaquin Valley of California. This included triplicate tests of each of five land preparation operations: stubble-disking, chiseling, disking, floating and land planing. All tests were performed at the Terranova Ranch in Helm/Fresno County in September of 1991.

The sampling strategy was based on the use of a "box model" that uses a mass balance approach (characteristic of exposure profiling) but with a remote downwind sampling array (characteristic of upwind-downwind sampling). However critical information on sampler placement and operation is missing from the report.

Apparently, an array of multiple low-volume PM-10 samplers (with a 3.3 m sampling height) was positioned along the downwind edge of the agricultural field being tested. At one downwind location, a vertical array of TSP samplers (with size segregation above and below 2.5 μm) at four heights (3, 5, 7, and 9 m) was operated. There was no vertical characterization of the upper portion of the plume (above a height of 3.3 m) because of the "limited physical height of the mounting pole."

Unfortunately, no data are provided in the report as to (a) the number and locations of samplers operated at a height of 3.3 m; (b) the duration of sampling; or (c) the point values of PM-10 concentration measured. These data are critical in assessing the soundness of the sampling strategy. Therefore the test data must be rated C, pending publication of the critical items listed above.

Another item of concern is the nonrestrictive meteorological requirements for valid field tests, as follows:

1. Wind direction from upwind to downwind sample location had an average angular variation of no more than ±45° from the sampling axis for the sampling period. Additionally 60 percent of the 10 minute averages must fall with ±45° throughout each tests.

2. The average wind speed was a minimum of 0.89 m/s (2 miles/hr).

The results of the tests of agricultural tilling in the form of single-valued emission factors, are shown in Table 4-2. No definition of the "±" values is provided. If the four single-valued emission factors are proposed as separate factors, the rating of each factor must be reduced to a rating of E because only one site was tested in developing each factor (see Table 3-1, Codes 5 and 6). On the other hand, if the four emission factors are to be combined to form one average factor for tilling operations, and the tests were performed on separate fields, the factor would be rated D (see Table 3-1, Code 2).

Also shown in Table 4-2 are the values produced by applying the current AP-42 emission factor equation. Notwithstanding questions about their validity, the comparisons show agreement within the predictive accuracy of the current AP-42 emission factor equation for agricultural tilling. In fact, with the exception of stubble disking and chiseling, which generally entail less soil disturbance than operations tested in developing the current AP-42 emission factor equation, the agreement between the AP-42 equation and the site-specific emission factors is unusually good.

TABLE 4-2. SUMMARY OF FIELD TEST RESULTS FOR PM-10 MASS EMISSIONS FROM TESTED AGRICULTURAL PRACTICES

Agricultural operation	Silt content, %	Temp., °C	Relative humidity, %	Average box model emission rate, lb/acre	AP-42 emission rate, lb/acre	Ratio
Stubble disking	19.7±2.2	23±3	54±15	1.9±0.4	6.0±0.6	0.32
Chiseling	16.3±1.4	18±2	66±11	2.2±1.6	5.4±0.3	0.41
Disking	16.1±1.6	27±3	47±8	a	5.3±0.4	NA
Floating	16.3±1.4	29±5	43±13	4.5±1.6	5.3±0.3	0.84
Land Planing	23.3±1.3	27±1	47±0	5.8±2.2	6.7±0.3	0.87

[a]Results are in question due to invalid meteorological conditions. NA = not applicable.

Based on the above analysis, there is no reason at this time to modify the existing emission factor equation for agricultural tilling.

4.2 SUMMARY OF CHANGES TO AP-42 SECTION

Only the narrative sections on general process descriptions and control methods is recommended for revision to reflect the trend toward increasing use of lower disturbance tilling operations.

According to the existing Section 11.2.2, the quantity of dust emissions from agricultural tilling, per acre of land tilled, may be estimated using the following empirical expression:

$$E = k(5.38)(s)^{0.6} \quad \text{(kg/hectare)}$$

$$E = k(4.80)(s)^{0.6} \quad \text{(lb/acre)}$$

where:

E = emission factor

k = particle size multiplier (dimensionless)

s = silt content of surface soil (percent)

The particle size multiplier (k) in the equation varies with aerodynamic particle size range as follows:

Aerodynamic Particle Size Multiplier

Total particulate	Particle size range				
	< 30 μm	< 15 μm	< 10 μm	< 5 μm	< 2.5 μm
1.0	0.33	0.25	0.21	0.15	0.10

Equation 1 is currently rated A if used to estimate total particulate emissions, and B if used for a specific particle size range. The equation retains its assigned quality rating if applied within the range of surface soil silt content (1.7 to 88 percent) that was tested in developing the equation. Also, to retain the quality rating of Equation 1 applied to a specific agricultural field, it is necessary to obtain a reliable silt value(s) for that field. The sampling and analysis procedures for determining agricultural silt content are given in Reference 1. In the event that a site specific value for silt content cannot be obtained, the mean value of 18 percent may be used, but the quality rating of the equation is reduced by one level.

References for Section 4

1. T. A. Cuscino, Jr., et al., *The Role Of Agricultural Practices In Fugitive Dust Emissions*, California Air Resources Board, Sacramento, California, June 1981.

2. C. Cowherd, Jr., et al., *Development Of Emission Factors For Fugitive Dust Sources*, EPA-450/3-74-037, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.

3. R. G. Flocchini, et al., *Study Of Fugitive PM-10 Emissions From Selected Agricultural Practices On Selected Agricultural Soils*, Prepared for San Joaquin Valley Unified APCD, U. S. Environmental Protection Agency, and the California Air Resources Board, April 1994.

5. DRAFT AP-42 SECTION 9.1

The proposed revision to AP-42 Section 9.1 is presented on the following pages as it would appear in the document.

DRAFT

This is preliminary material, in draft form, for purposes of review. This material must not be quoted, cited, or in any other way considered or used as final work.

9.1 AGRICULTURAL TILLING

9.1.1 General

The two universal objectives of agricultural tilling are the creation of the desired soil structure to be used as the crop seedbed and the eradication of weeds. Plowing, the most common method of tillage, consists of some form of cutting loose, granulating and inverting the soil, and turning under the organic litter. Implements that loosen the soil and cut off the weeds but leave the surface residue in place have recently become more popular for tilling in dryland farming areas. The conventional moldboard (self-scouring) plows, chisels and disks of the 1970s have been largely replaced by improved equipment (e. g., modified chisels, sweeps, disks, coulters and subsurface cutters) that requires less frequent use than former implements. Often the depth of soil disturbance is less than produced by conventional tilling equipment.

During a tilling operation, dust particles from the loosening and pulverization of the soil are injected into the atmosphere as the soil is dropped to the surface. Dust emissions are greatest during periods of dry soil and during final seedbed preparation.

9.1.2 Emissions and Predictive Equation[1-2]

The quantity of dust from agricultural tilling is proportional to the area of land tilled. Also, emissions depend on surface soil texture and surface soil moisture content, conditions of a particular field being tilled.

Dust emissions from agricultural tilling have been found to vary directly with the silt content (defined as particles <75 micrometers in diameter) of the surface soil depth (0 to 10 cm [0 to 4 in.]). The soil silt content is determined by measuring the proportion of dry soil that passes a 200 mesh screen, using ASTM-C-136 method. Note that this definition of silt differs from that customarily used by soil scientists, for whom silt is particles from 2 to 50 micrometers in diameter.

Field measurements indicate that dust emissions from agricultural tilling are not significantly related to surface soil moisture, although limited earlier data had suggested such a dependence. This is now believed to reflect the fact that most tilling is performed under dry soil conditions, as were the majority of the field tests.

Available test data indicate no substantial dependence of emissions on the type of tillage implement (for those implements tested), if operating at a typical speed (for example 8 to 10 km/hr [5 to 6 mph]).

The quantity of dust emissions from agricultural tilling, per acre of land tilled, may be estimated with a rating of A or B (see below) using the following empirical expression:

$$E = k(5.38)(s)^{0.6} \text{ (kg/hectare)} \quad (1)$$

$$E = k(4.80)(s)^{0.6} \text{ (lb/acre)}$$

where:

E = emission factor

k = particle size multiplier (dimensionless)

s = silt content of surface soil (%)

The particle size multiplier (k) in the equation varies with aerodynamic particle size range as follows:

Aerodynamic particle size multiplier

	Particle size range				
Total particulate	< 30 μm	< 15 μm	< 10 μm	< 5 μm	< 2.5 μm
1.0	0.33	0.25	0.21	0.15	0.10

Equation 1 is rated A if used to estimate total particulate emissions, and B if used for a specific particle size range. The equation retains its assigned quality rating if applied within the range of surface soil silt content (1.7 to 88 percent) that was tested in developing the equation. Also, to retain the quality rating of Equation 1 applied to a specific agricultural field, it is necessary to obtain a reliable silt value(s) for that field. The sampling and analysis procedures for determining agricultural silt content are given in Reference 2. In the event that a site specific value for silt content cannot be obtained, the mean value of 18 percent may be used, but the quality rating of the equation is reduced by one level. The mean value of 18 percent is the geometric mean of the test site values listed in Reference 2.

9.1.3 Control Methods[2-3]

In general, control methods are not applied to reduce emissions from agricultural tilling. Irrigation of fields before plowing will reduce emissions, but in many cases, this practice would make the soil unworkable and would adversely affect its subsequent characteristics.

Emissions from agricultural tilling can be reduced through conservation practices in the form of operational modifications that include (a) the use of novel low-disturbance implements or (b) the alteration of cultural techniques to eliminate some operations altogether. Although supporting field data are not available, use of farm implements designed to cause less soil disturbance during tilling is expected to entail lower emissions.

Control methods for agricultural activities aimed primarily at reduction of emissions from wind erosion include such practices as continuous cropping, stubble mulching, strip cropping, applying limited irrigation to fallow fields, building windbreaks, and using chemical stabilizers. However, for the most part, no field data are available to indicate the effects of these control methods on associated emissions from agricultural tilling. With regard to soil moisture, emissions may be assumed to be inversely dependent on the square of the surface soil moisture contents.[2]

References for Section 9.1

1. C. Cowherd, Jr., *et al.*, *Development Of Emission Factors For Fugitive Dust Sources*, EPA-450/3-74-037, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.

2. T. A. Cuscino, Jr., *et al.*, *The Role Of Agricultural Practices In Fugitive Dust Emissions*, California Air Resources Board, Sacramento, CA, June 1981.

3. G. A Jutze, *et al.*, *Investigation Of Fugitive Dust - Sources Emissions And Control*, EPA-450/3-74-036a, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.